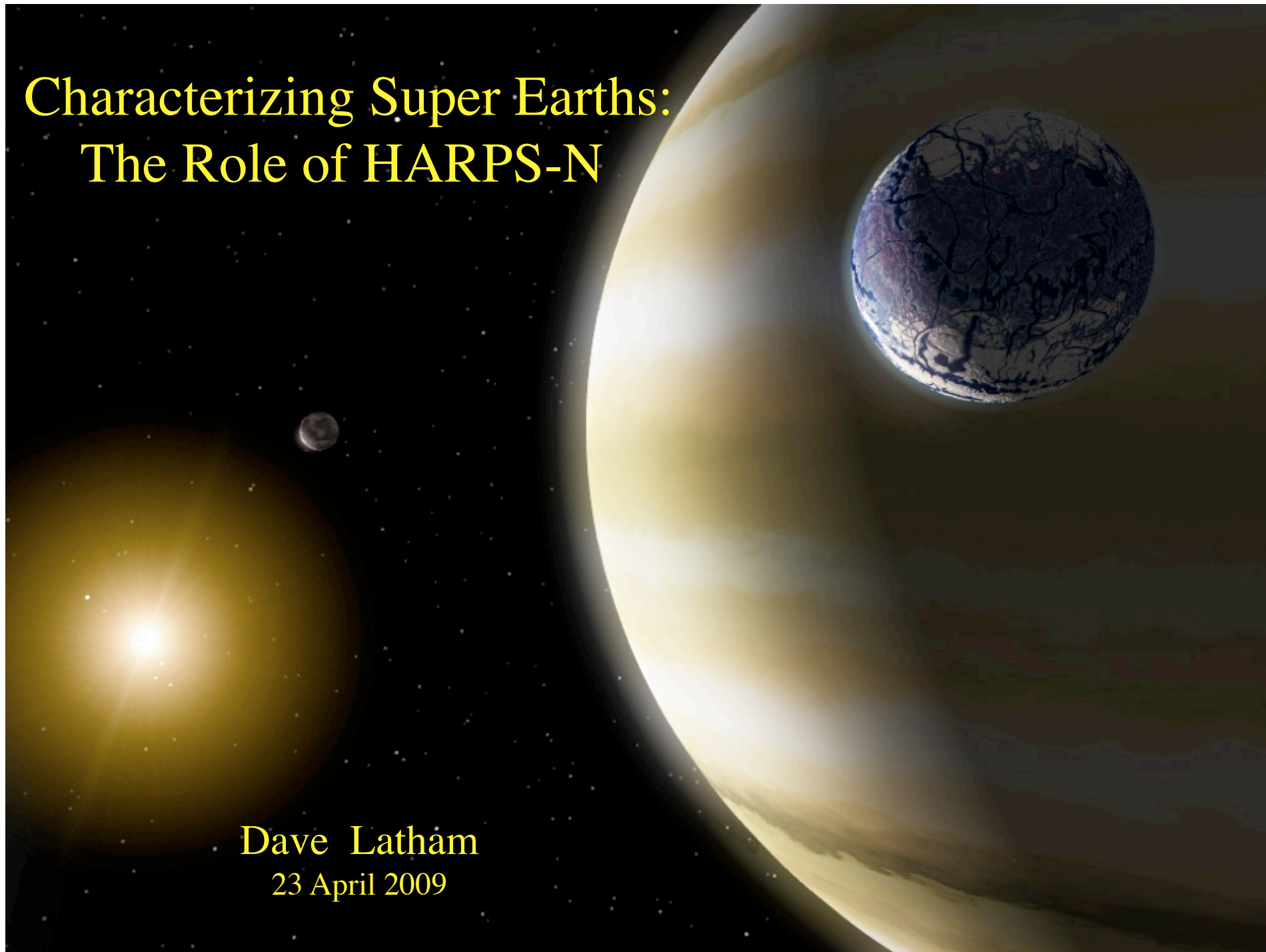


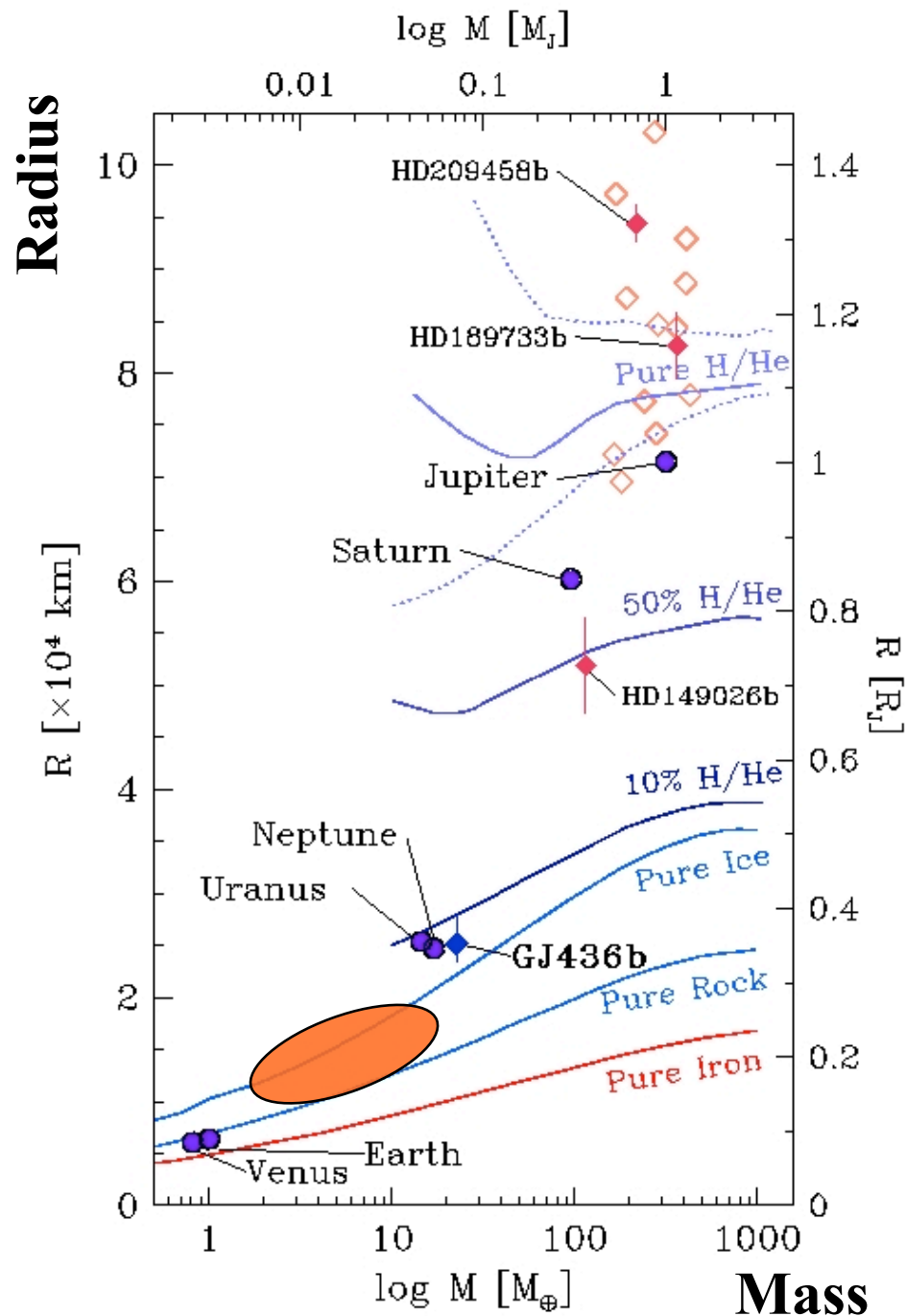
Characterizing Super Earths: The Role of HARPS-N

Dave Latham
23 April 2009



Transiting Planets: Why All the Excitement?

- ~15% of known exoplanets transit their star
- Source of real planetary astrophysics
 - Planet radii and masses (and thus densities)
 - Radius from transit light curve (area blocked)
 - Mass from radial-velocity orbit of host star together with orbital inclination from light curve
 - Spectroscopy of exoplanet atmospheres
- Just now reaching Super Earths (1-10 M_E)

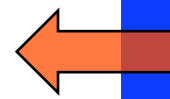


Mass vs. Radius

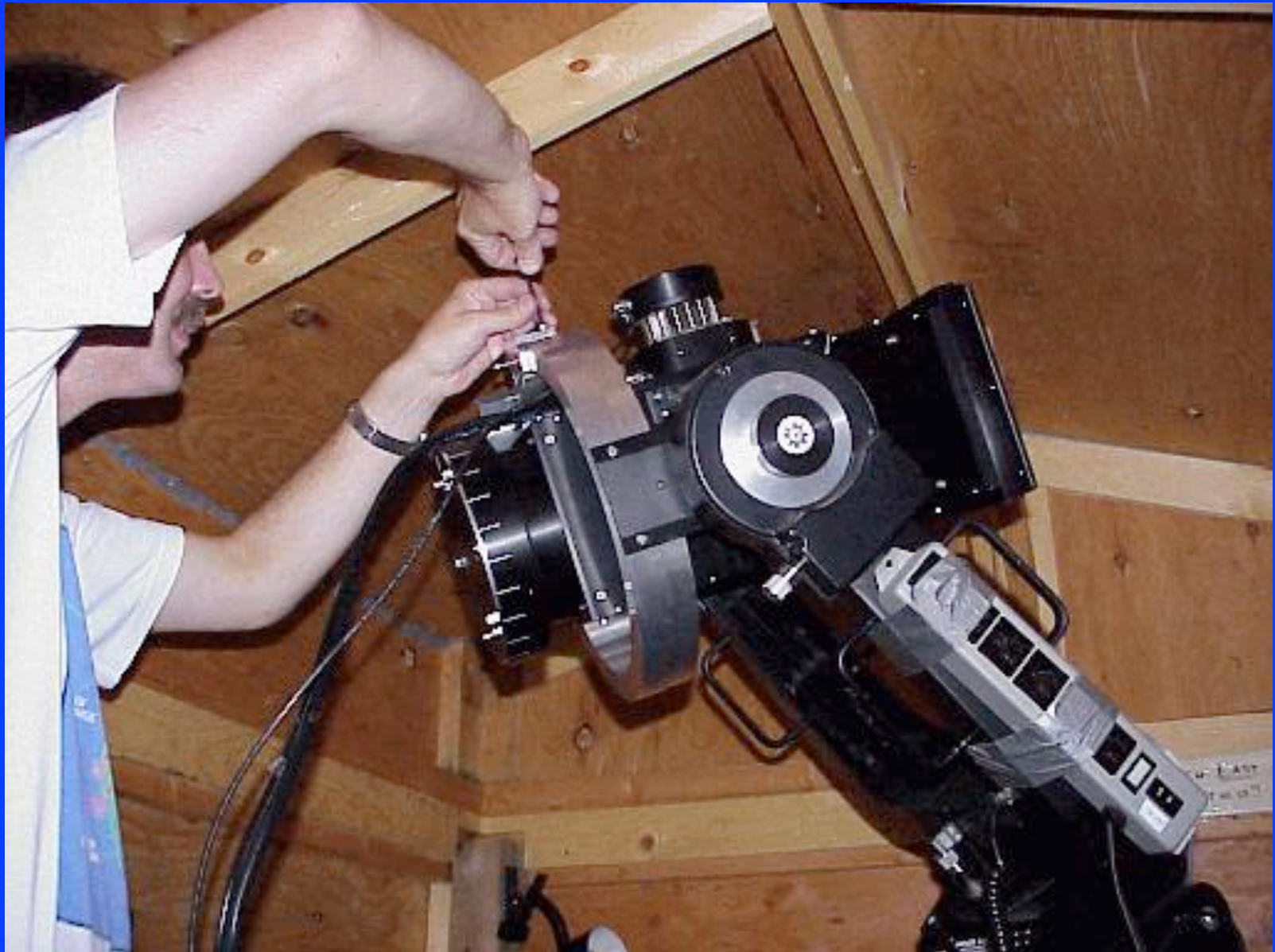
} Hot Jupiters

Super-Earths

Mass range:
1 - 10 Earths



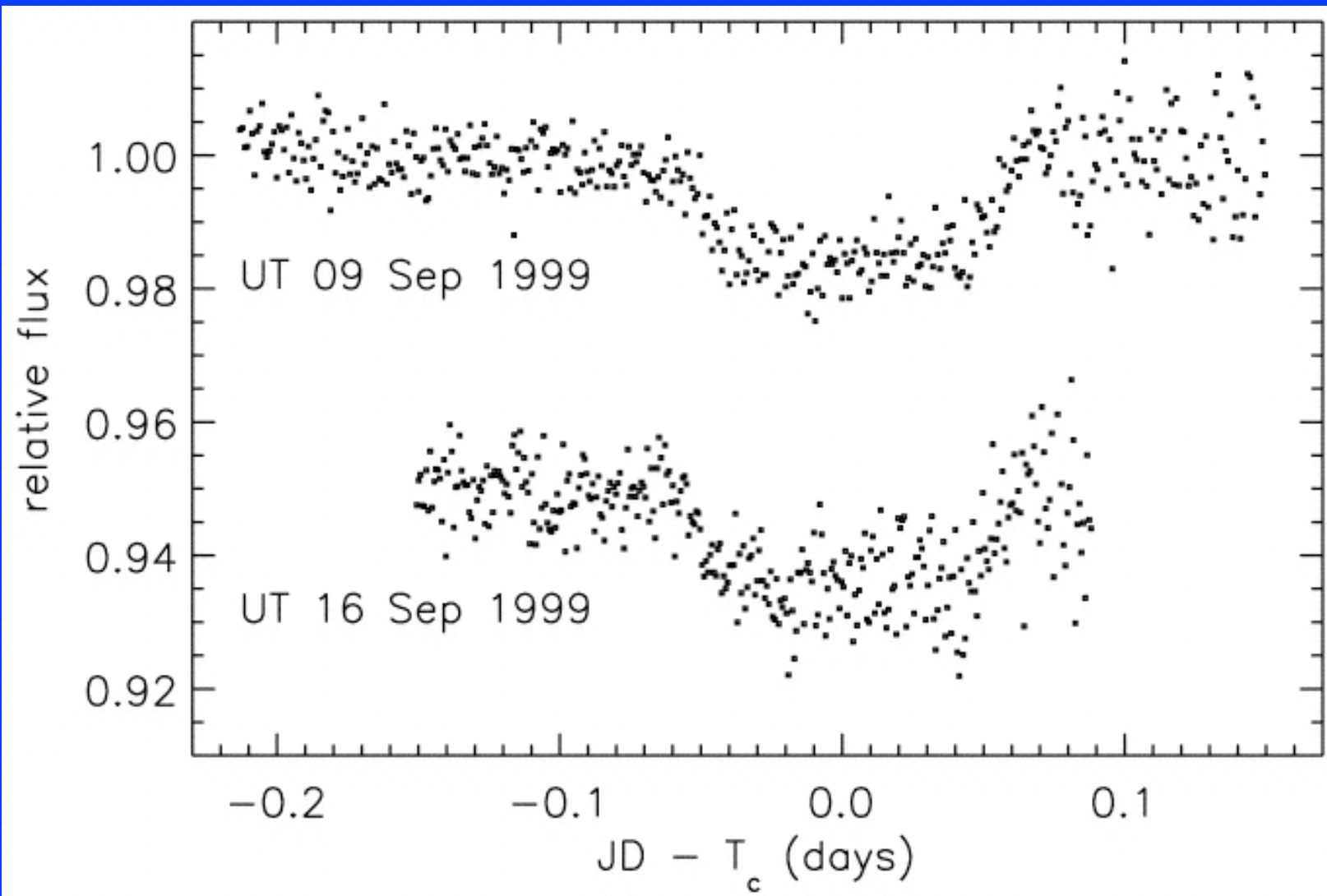
Tim Brown and Stare



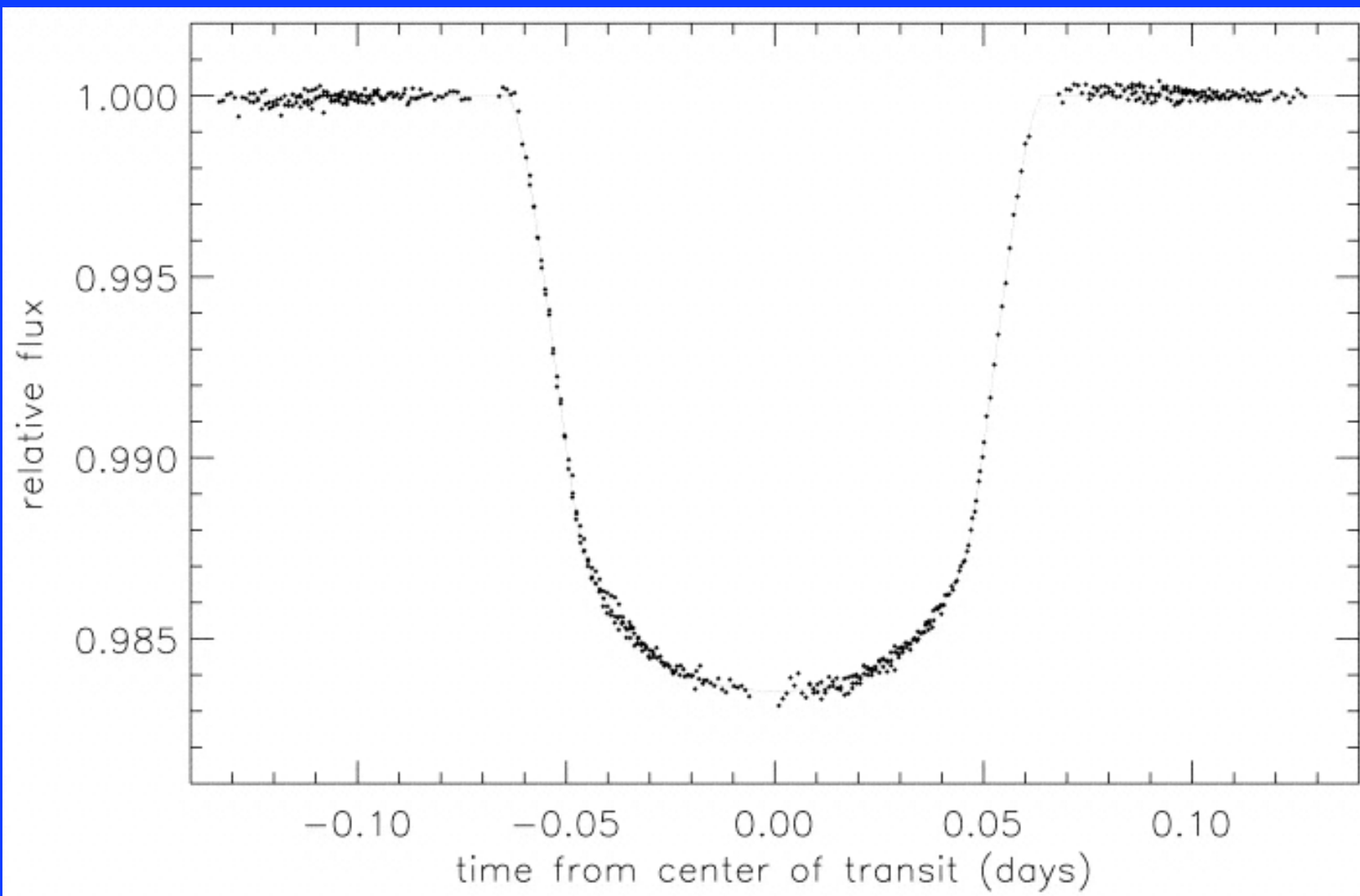
Dave Charbonneau

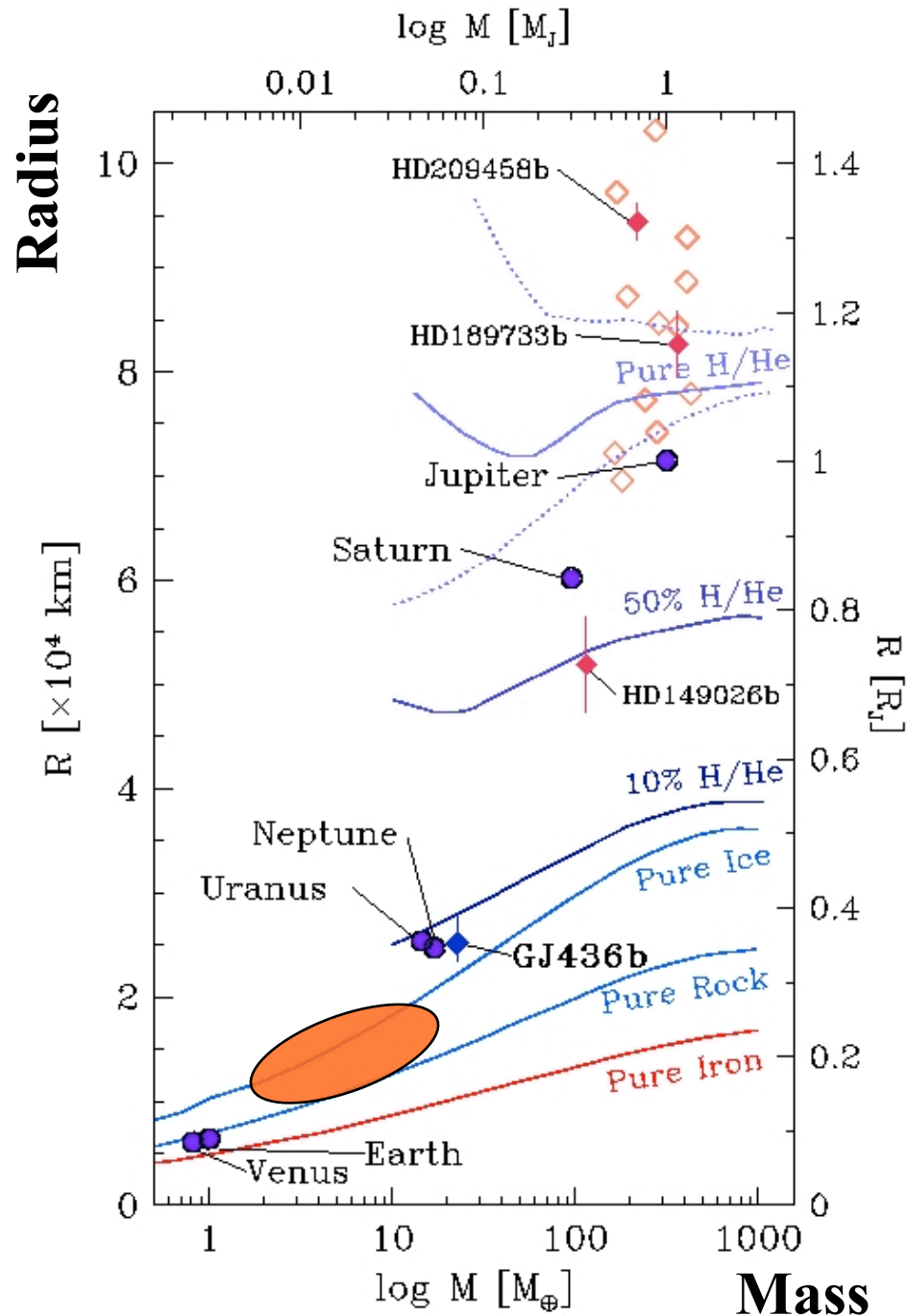


HD 209458



HST – STIS Light Curve



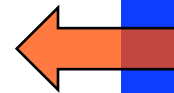


Mass vs. Radius

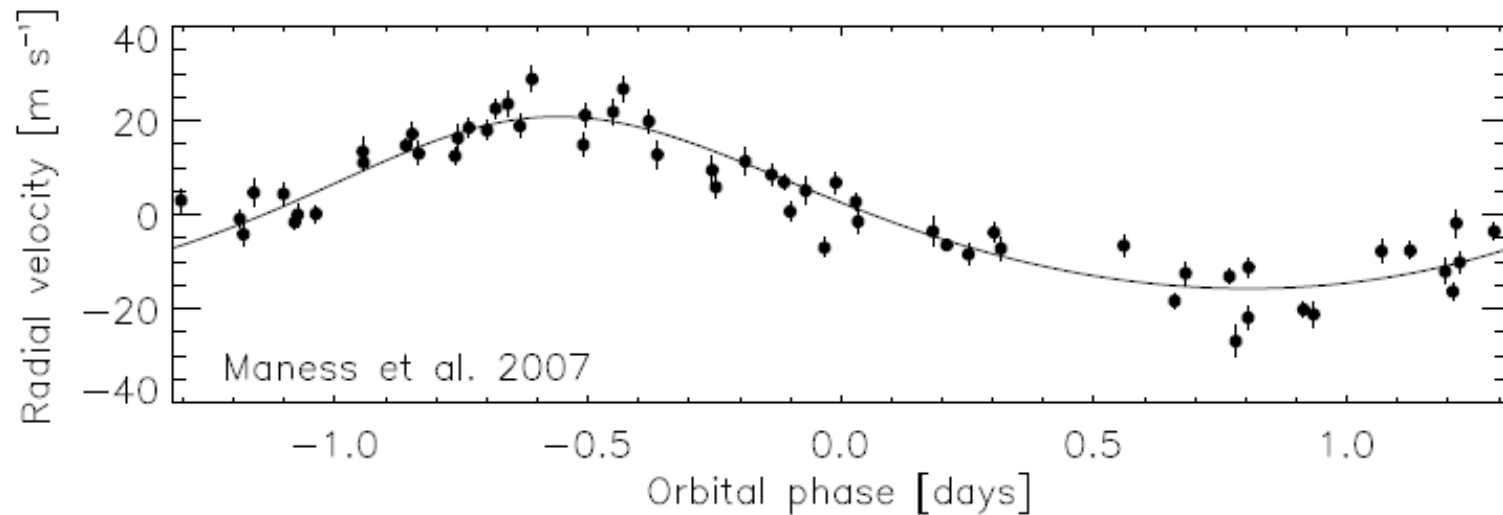
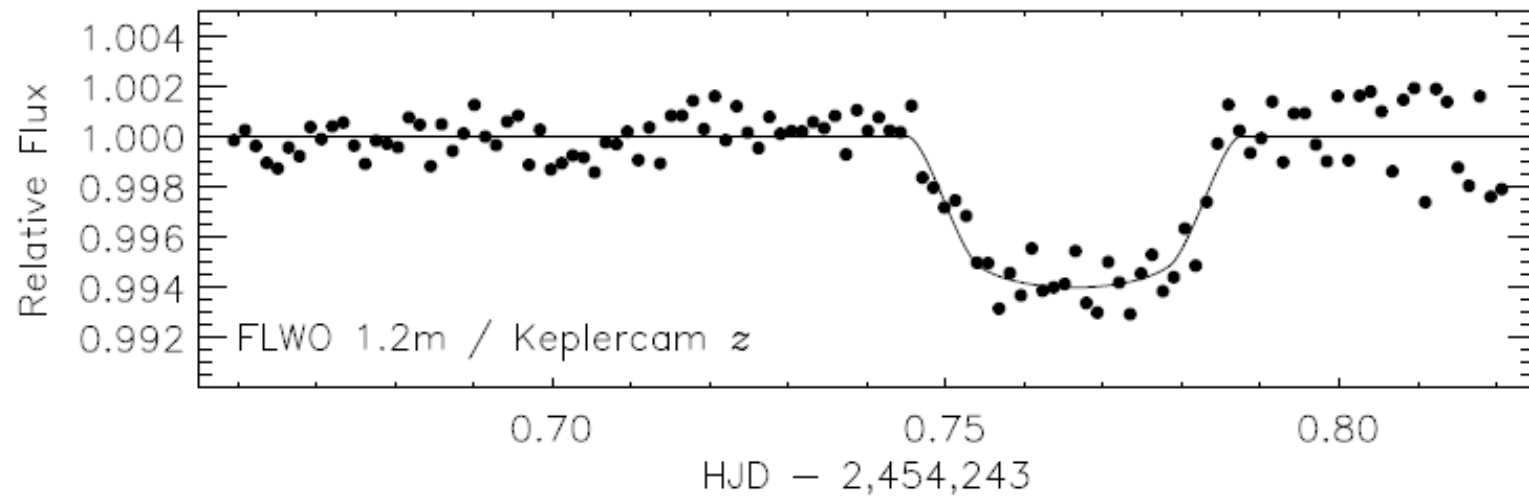
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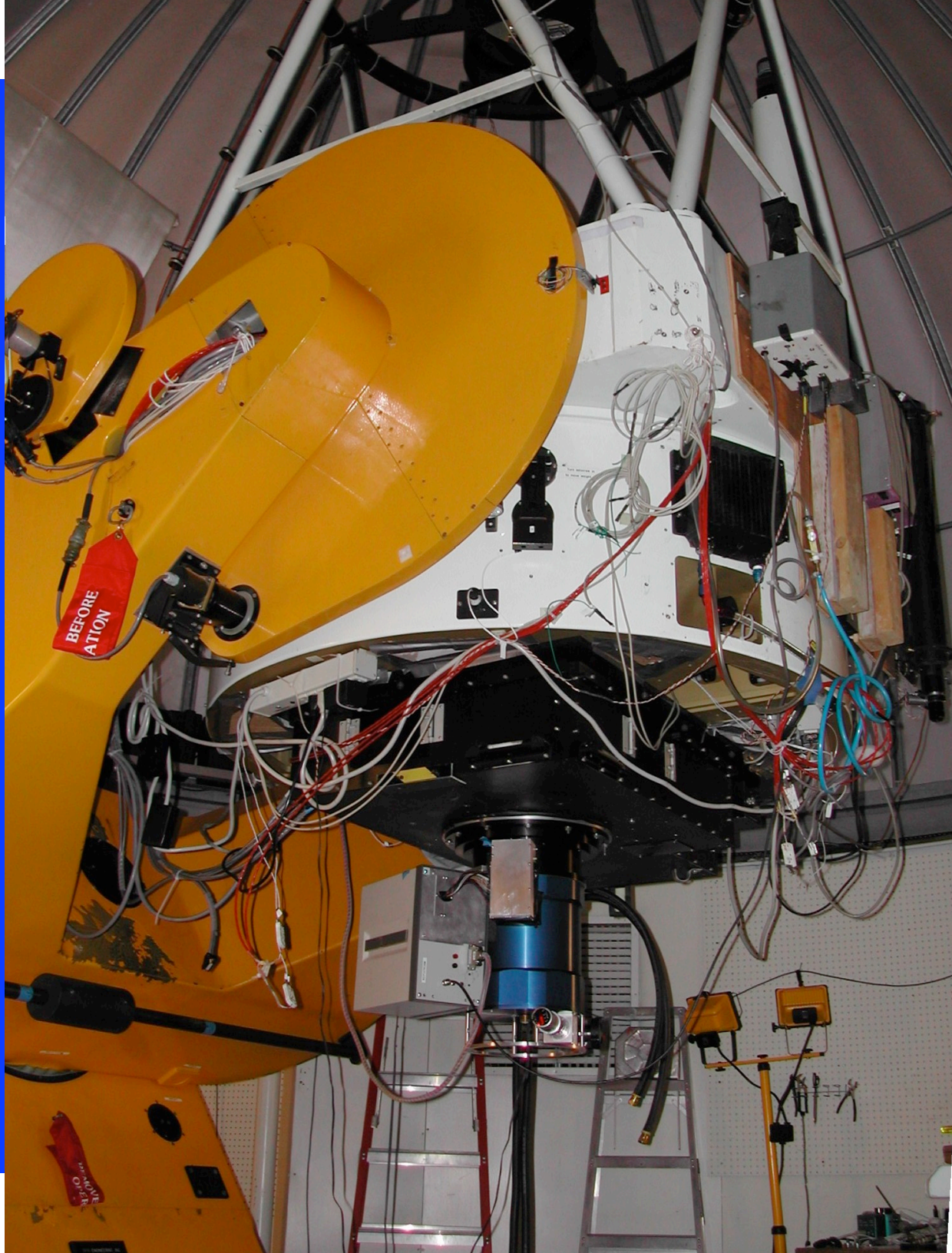


Gliese 436: $R=3.8 R_{\text{Earth}}$, $M=23 M_{\text{Earth}}$



Wide-Angle Photometric Surveys

- Confirmation requires an orbit for host star
 - Eliminate eclipsing binary imposters
 - Big star eclipsed by little star (e.g. F/M)
 - Eclipsing binary diluted by third star in image
 - Physical triples (and quadruples)
 - Accidental alignments
 - Derive planetary mass relative to host star
- Need high-quality light curve
 - Lots of information in detailed shape





Doppler State-of-the-Art

Quietest, slowly rotating solar-type stars

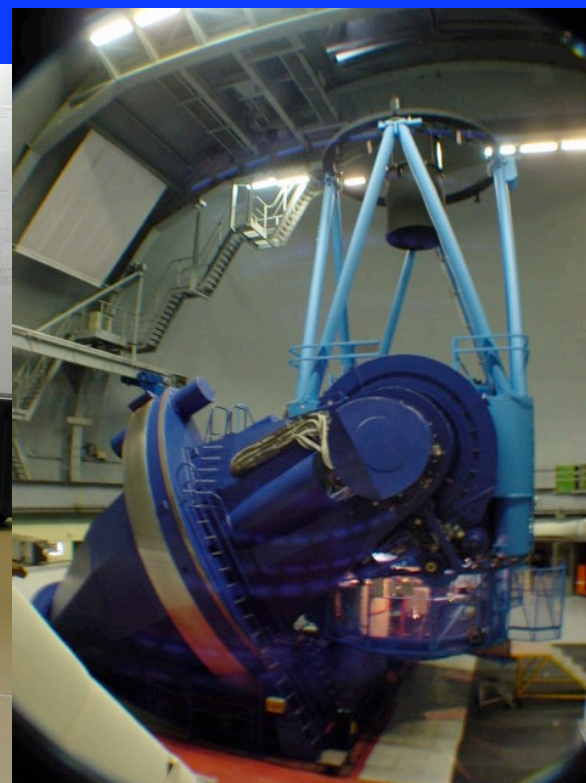
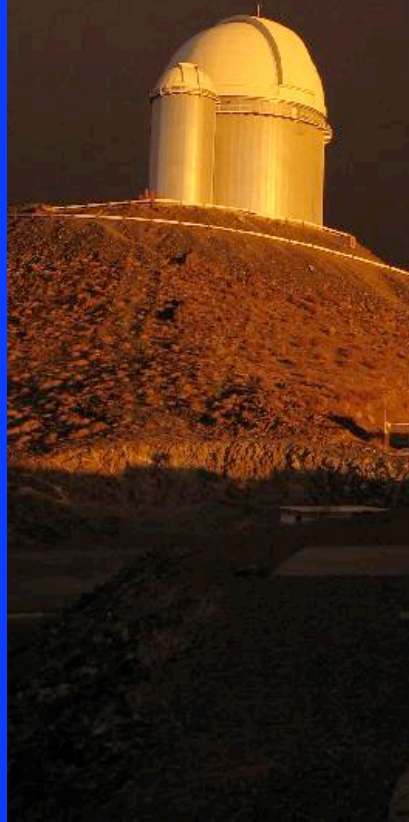
- Keck 10-m with HIRES: ~ 1 m/s
 - Slit spectrometer with Iodine absorption cell
 - 1 m/s requires ~ 2 hours at $V=12$
- ESO 3.6-m with HARPS: ~ 50 cm/s
 - Fiber fed with simultaneous Th-Ar
 - 1 m/s requires 1 hour at $V=12$
 - Located in Chile

The 'old' HARPS planet-search program

ESO 3.6 – La Silla

- Geneva Observatory
- Physikalisches Institut, Bern
- Haute-Provence Observatory
- Service d'Aéronomie, Paris
- ESO

→ **1 m/s**

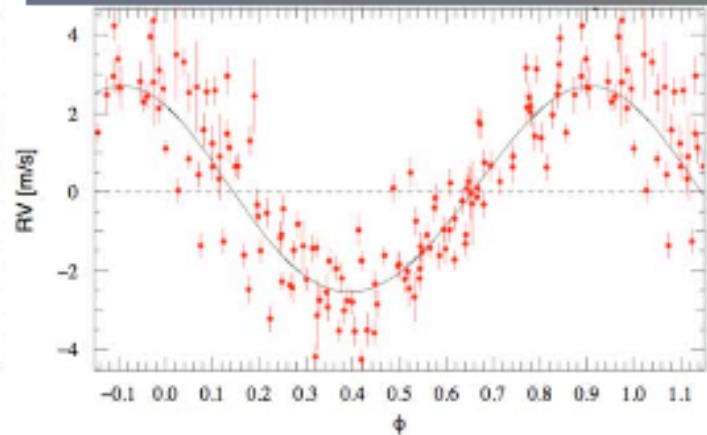
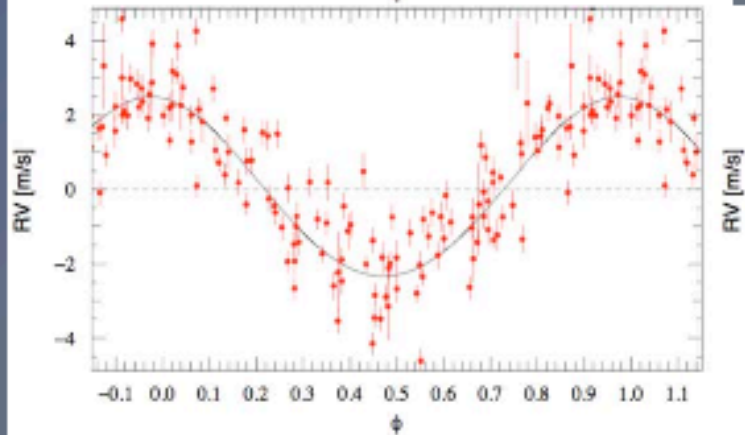
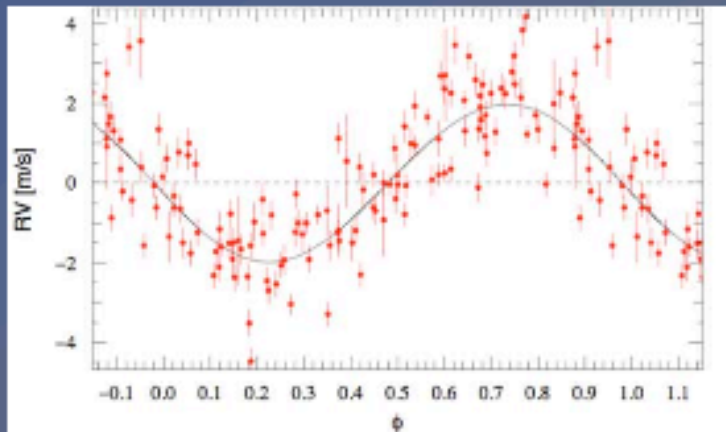
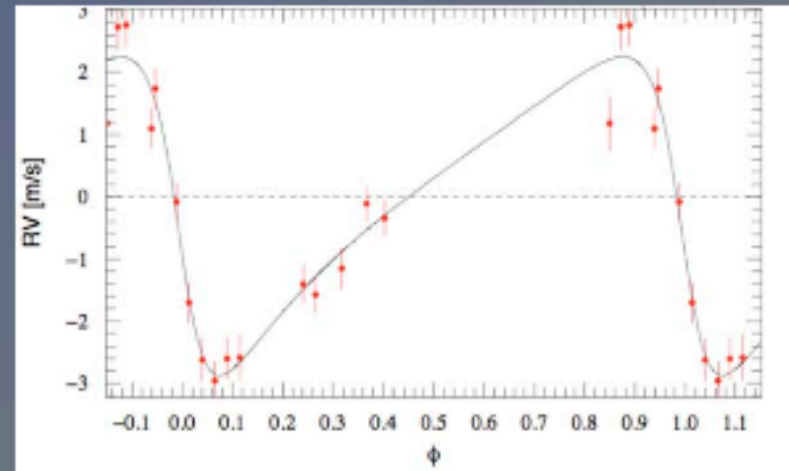


An emerging population of Hot Neptunes and Super-Earths

(from C. Lovis)

Mayor et al. 2008, submitted

$P = 39.6$ days
 $e = 0.51$
 $m \sin i = 9.7 M_{\oplus}$

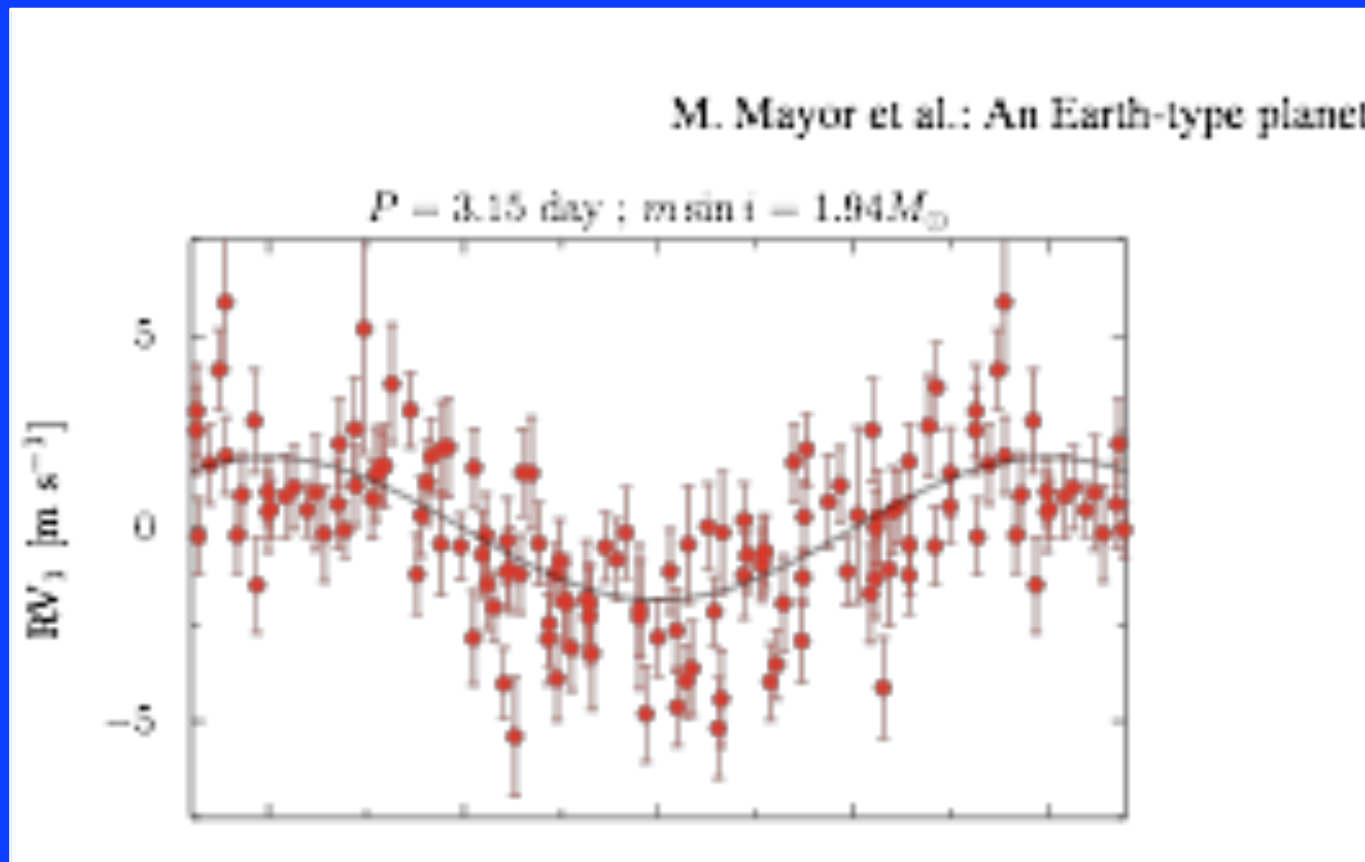


$P_1 = 4.31$ days
 $e_1 = 0.02$
 $m_1 \sin i = 4.3 M_{\oplus}$

$P_2 = 9.62$ days
 $e_2 = 0.03$
 $m_2 \sin i = 6.9 M_{\oplus}$

$P_3 = 20.5$ days
 $e_3 = 0.04$
 $m_3 \sin i = 9.7 M_{\oplus}$

GJ581e: rms O-C = 1.5 m/s, four planet fit



Achieving better than 1 m/s: Stability & Simultaneous ThAr reference

$\Delta RV = 1 \text{ m/s}$



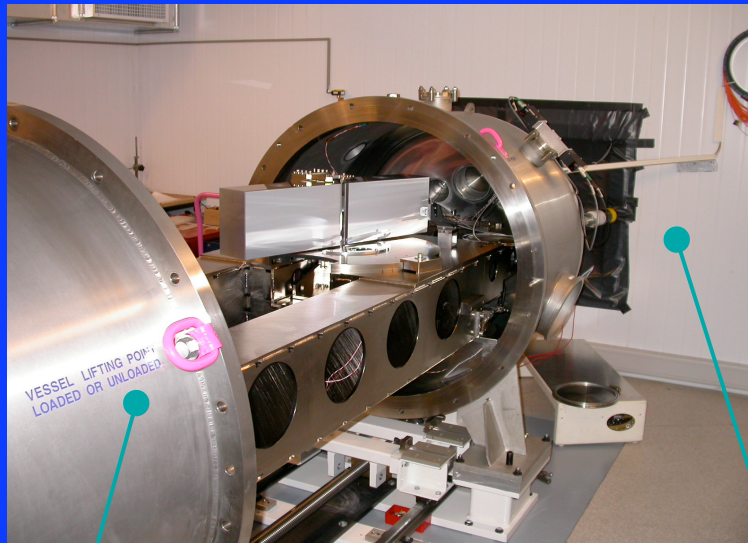
$\Delta\lambda = 0.00001 \text{ \AA}$



15 nm



1/1000 pixel



Vacuum operation

$\Delta RV = 1 \text{ m/s}$



$\Delta T = 0.01 \text{ K}$



$\Delta p = 0.01 \text{ mBar}$

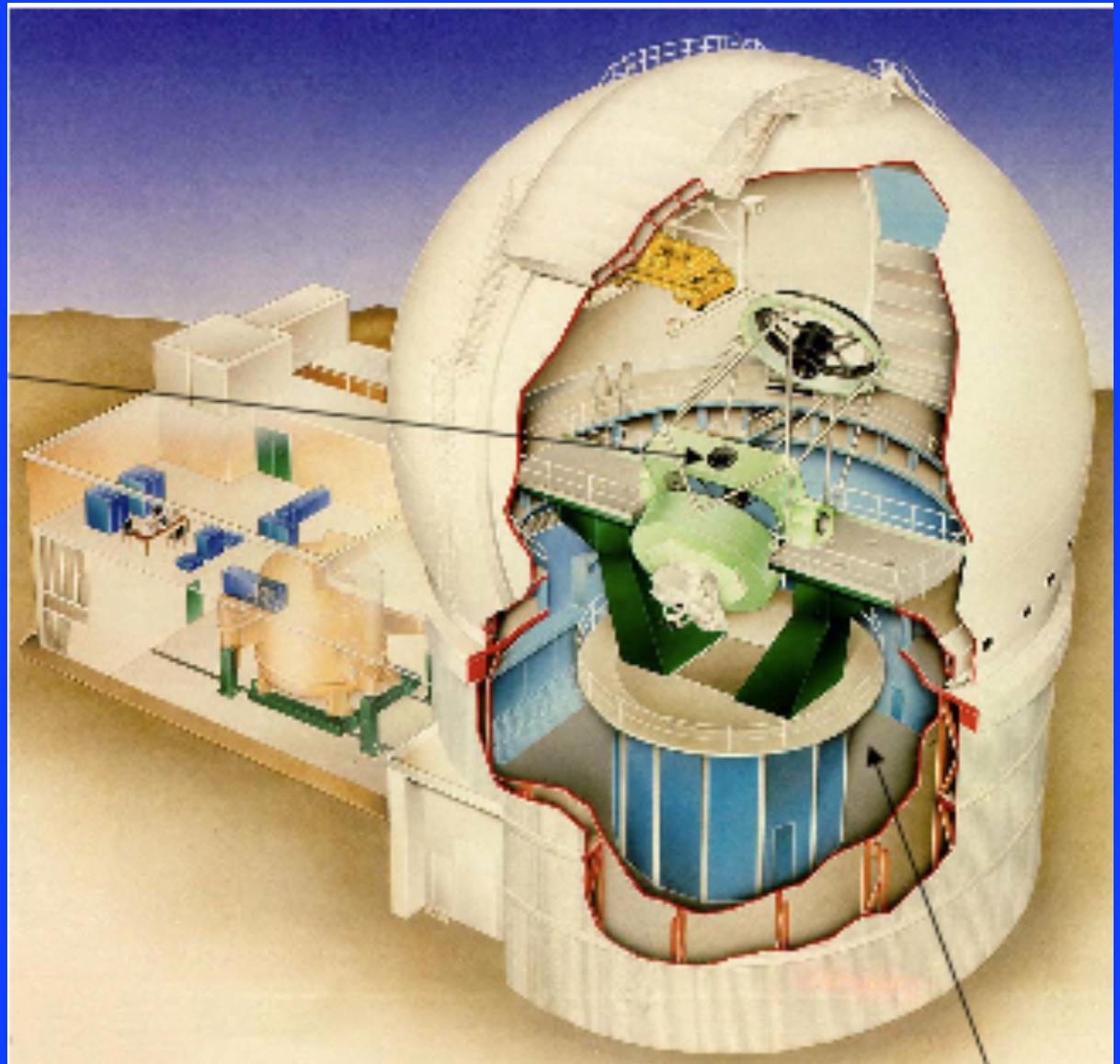
Temperature control

HARPS-N Spectrometer on WHT

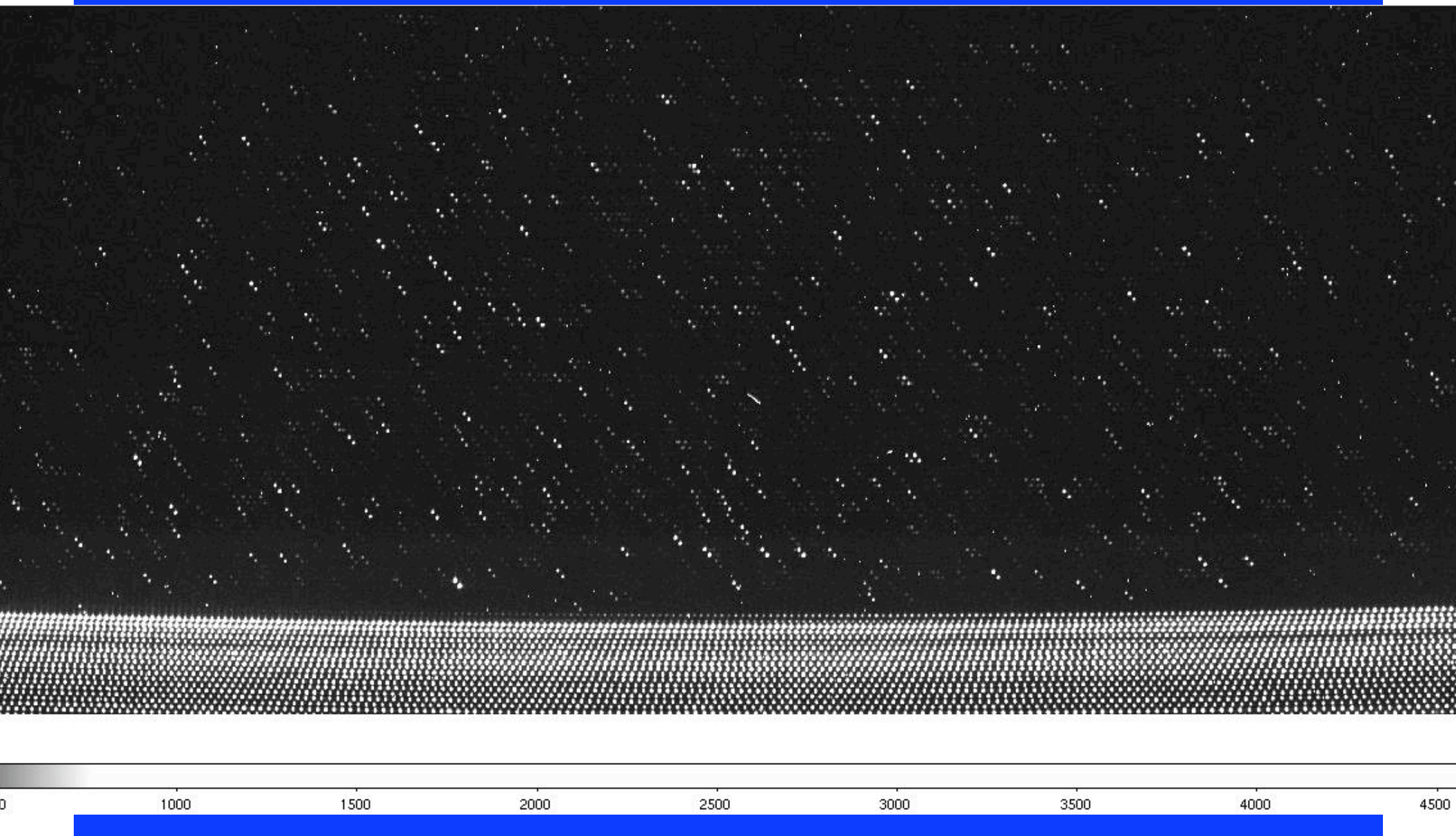
Harvard Origins
and SAO/HCO
with Geneva
on the
William Herschel
4.2-m telescope

Ready for Kepler
follow up in 2011

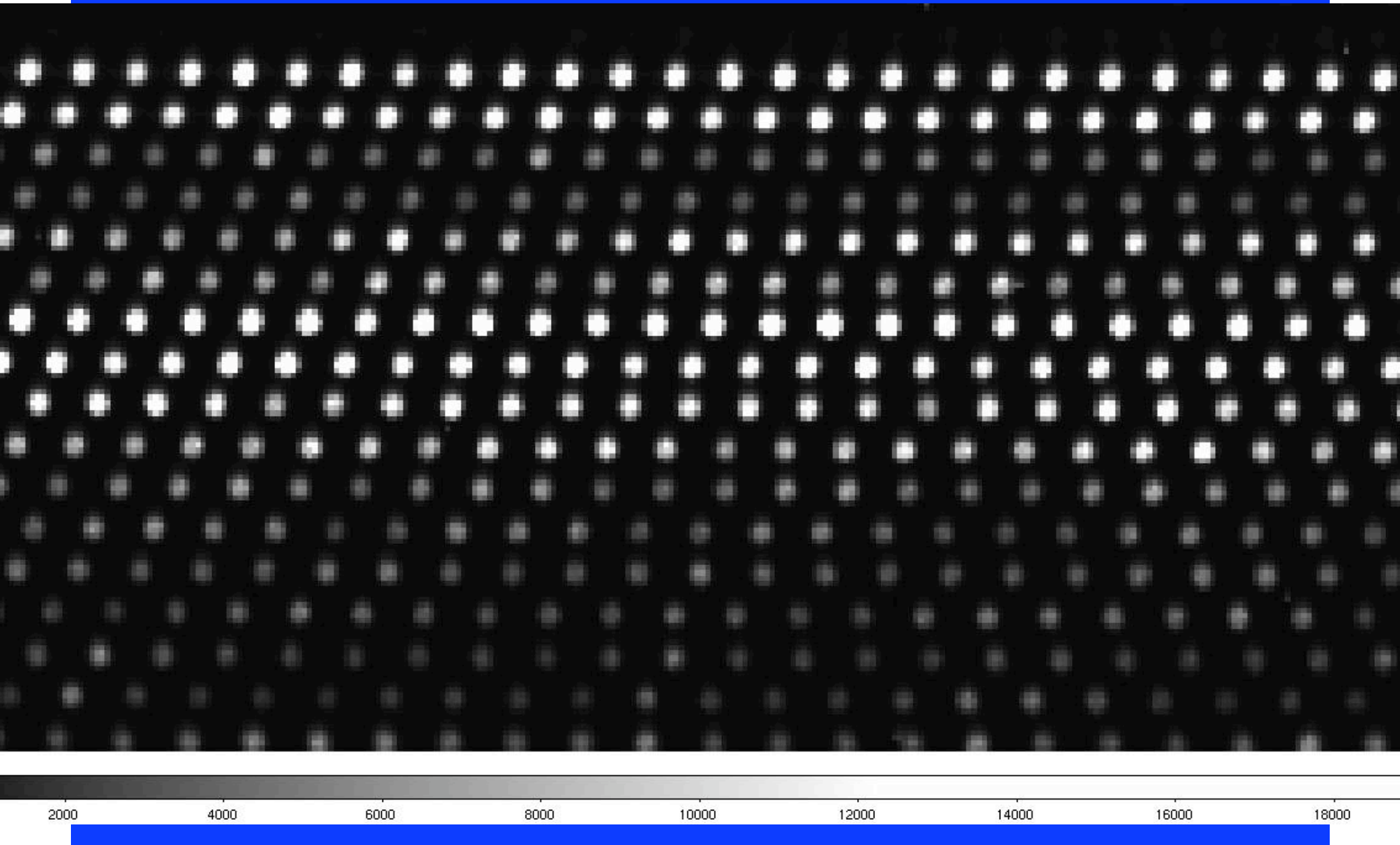
A HARPS clone,
with improvements...



ThAr vs. Comb - FLWO, Aug. 2008



Comb lines (zoomed in) - FLWO, Aug. 2008





Research focus:

Does the diversity of planetary environments map onto a diversity of biochemistries?

Super Earths and Life sub-project:

Study the diversity of global geochemistry on Super-Earths and Earth analogs.